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3,277,766

EXPLOSIVELY RELEASABLE BOLT

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Fig. 1.

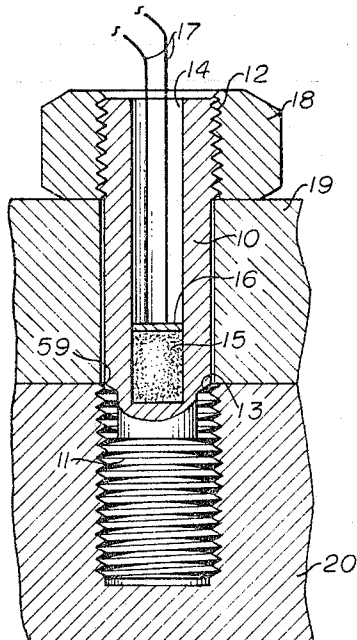


Fig. 2.

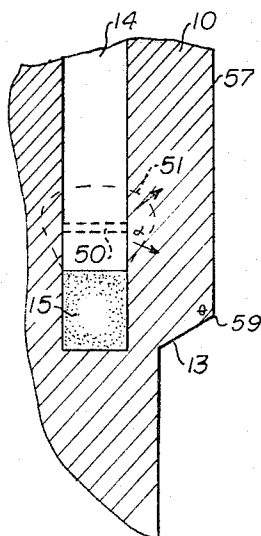


Fig. 3.

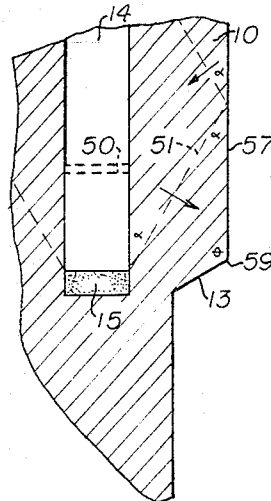


Fig. 4.

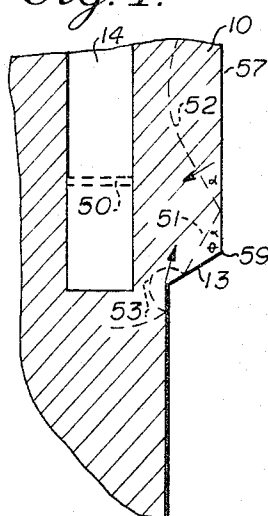


Fig. 5.

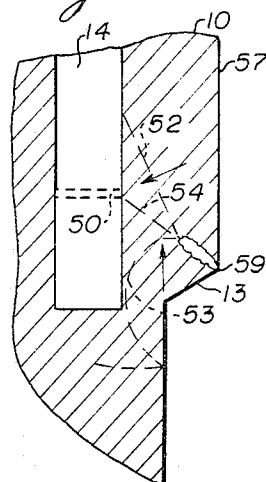
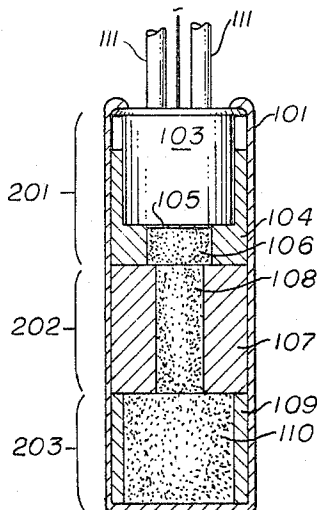


Fig. 6.



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EXPLOSIVELY RELEASABLE BOLT

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3 Claims. (Cl. 85—1)

The invention described herein was made in the course of, or under, Contract No. AT(29-1)-789, Purchase Order No. 82-4499 with the United States Atomic Energy Commission, and said invention may be manufactured and used by or for the Government of the United States of America without the payment of any royalties thereon or therefor.

This invention relates to bolts and like fasteners and in particular to fasteners released by the firing of an explosive charge.

Explosive bolt devices of the existing art generally rely on the excessive pressure of contained gases resulting from ignition of an explosive charge that burst or fragment the bolt somewhat in the manner of a hand grenade. Naturally such devices fill the surroundings with flying shrapnel endangering persons and equipment in the vicinity and often rendering the equipment inoperative. Such an untoward result can be very costly under circumstances in which such fasteners are often employed, e.g., in space vehicles or the like wherein the fasteners may be used for securing detachable portions, jettisoning fuel tanks, and the like.

The present invention utilizes the energy generated by an explosive charge in a manner not dependent upon contained gas pressure to achieve a precisely directed and controlled disruptive separation of a bolt stem. In the device of the invention, the arrangement and shape of the bolt stem and the disposition of the explosive charge is especially adapted to cause the generation and collision of tensile (dilatational or rarefaction) shock waves along a plane in a stress additive fashion so that the tensile strength of the material is exceeded thereat and the bolt separates in that region. It should be noted that by using the above principle, the energy released in the explosion is, in effect, focused on a small area in order to achieve greater efficiency. Thus a smaller amount of explosive material is needed. Also, with carefully selected charge sizes little momentum is acquired by the separated sections and only lightweight restraining guards are needed, at most, to prevent destructive movement of the pieces.

It is, therefore, an object of this invention to provide a device releasable upon the discharge of an explosive charge.

It is a further object of this invention to provide a fastening device releasable upon the detonation of an explosive charge contained therein without endangering persons or equipment located nearby.

It is a further object of this invention to provide a fastening device frangible upon the detonation of an explosive charge contained therein imparting only low accelerating forces to the separated parts.

It is a further object of this invention to provide a fastening device utilizing the colliding shock waves resulting from the detonation of a high explosive to cause separation of said fastening device.

It is a further object of this invention to provide an explosively releasable fastening device wherein the explosive energy is efficiently used thus requiring a minimum amount of explosive material.

Other and more particular objects of this invention will be manifest upon study of the following detailed description when taken together with the accompanying drawing, in which:

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FIGURE 1 is a longitudinal section through the bolt, and

FIGURES 2, 3, 4 and 5 illustrate, sequentially, the propagation of the compressive and reflected tensile shock wave fronts caused by the detonation of the high explosive at various times during and after detonation, and

FIGURE 6 is a longitudinal section through one type of cartridge containing high explosive material arranged to achieve symmetrical detonation.

Although the description which follows shows an embodiment of this invention in the form of a stud, other forms and shapes of fasteners such as bolts, rivets, screws or the like could easily be adapted to incorporate this invention by a person of ordinary mechanical ability.

Referring to FIGURE 1 the device of this invention comprises a rod-like stud body 10 having threaded portions 11 and 12 proximate the ends, an externally tapered section 13 having a sharp edged corner 59 and a generally cylindrical hole 14 entering from threaded end 12 and terminating in a transverse end wall and having its cylindrical axis coincident with the longitudinal axis of stud body 10. In this embodiment, conically tapered section 13 is arranged to slope inwardly at an angle of approximately 60° to the longitudinal axis of stud body 10 toward threaded end 11. This particular slope has been found by experiment to produce excellent results. It must be noted that this slope is critically dependent upon detonation properties of the explosive material used and it determines the plane of collision of the reflected tensile shock waves and thus the plane of separation or fracture as set forth more fully hereinafter. Hole 14 is arranged to receive a high explosive charge 15. Such an explosive charge may be either pressed in place or be in the form of a cartridge or encapsulated combination as illustrated by FIGURE 6 of high explosives and materials arranged to generate a transverse explosive detonation front proceeding uniformly along the longitudinal length of the explosive charge. Various explosive materials such as PETN (pentaerythritoltetranitrate), RDX (cyclotrimethylenetriaminetrinitrate) or the like have been found to produce excellent results. It must be further noted that for best results, hole 14 should be arranged to extend a depth sufficient to permit the bottom of explosive charge 15 to reach or extend slightly beyond the locus of collision which generally approaches the volume enclosed by tapered section 13.

Primary explosive detonating means 16 is provided proximate the end of explosive charge 15 nearest the opening of hole 14. Care must be taken to make sure that detonation of charge 15 is symmetrical, otherwise, the shock waves will not be symmetrical and will not efficiently sever the bolt stem. For this reason, initiation of detonating means 16 must be by a centrally located point source or means similarly purposeful to achieve even and symmetrical initiation of detonation of explosive charge 15. Wires 17 coupled to a bridge wire (not shown) and disposed in primary explosive 16 are provided in the instant embodiment as one means for electrically initiating detonation although detonating fuse, mechanical strikers, hammers or the like or other means could be used without departing from the concepts and method of operation of this invention.

In lieu of a pressed-in-place high explosive charge 15 with primary explosive detonating means 16, the detonator cartridge illustrated in FIGURE 6 has been found to produce excellent results. The cartridge comprises a tubular squib case 101 of copper, steel or similar material to form a shock wave impedance match with the bolt material, open at one end and containing consecutively arranged and abutting, high explosive charges 201, 202 and 203 to achieve a symmetrical pressure shock

wave, which propagates longitudinally. Primary detonation charge 201 comprises a bridge plug 103 against one end of which, and disposed midway in plug 104, is a disk of first detonating explosive material 105. In contact with explosive material 105 and filling cylindrical plug 104 flush with one end is second detonating explosive material 106. Abutting and in contact with the end of plug 104, containing explosive material 106, is secondary high explosive charge 202 comprising a thick walled cylinder 107 of steel, copper or the like, filled with a more powerful high explosive material 108. Abutting and in contact with the end of secondary high explosive charge 202 is tertiary high explosive charge 203 comprising a thin walled copper cylinder 109 containing high explosive material 110. The end of squib case 101 is crimped over bridge plug 103 to retain and maintain charges 201, 202 and 203 in intimate contact. Electrical leads 111 enter bridge plug 103 and are connected as to a bridge resistance heater wire, or like means, well known in the art to initiate detonation upon application of electrical current. Upon initiation, first explosive material 105, preferably, e.g., normal lead styphnate or the like, is caused to detonate in turn initiating detonation in second explosive material 106, preferably lead azide or the like. The detonation of second explosive material 106 in turn initiates detonation in the more powerful explosive material 108, preferably PETN or the like, confined within the central hole in thick walled cylinder 107 and having a length several times greater than its diameter. During is propagation down explosive material 108, some of the irregularities in the detonating wave front are smoothed out so that when such wave front reaches explosive material 110, it is essentially in a transverse plane. The planar detonation wave from explosive material 108 then symmetrically initiates detonation in explosive material 110, preferably, e.g., RDX or the like, generating a symmetrical plane-transverse shock wave as detonation progresses along the length of body of explosive material 110.

In a typical installation a nut 18 or the like, engageable with threaded portion 12 may be used to hold a plate 19 to base plate 20. Base plate 20 can be tapped, as shown in this embodiment to receive threaded portion 11 or drilled and arranged to be of a thickness so that a nut, cap-nut or the like can be engaged with the threaded portion 11 of stud body 10.

Care must be taken in the selection of material from which stud body 10 is fabricated. It has been found that fragment-free cuts are obtained over a wide range of explosive charge (146-350 mg. RDX) using SAE 4130 steel (cold finished and annealed) and SAE 4620, at room temperature and above. The body of the bolt in this case had outside diameters of about 0.551 inch below and 0.699 inch above the tapered section using a hole diameter for the explosive charge of about 0.261 inch. A typical charge would comprise 6 mg. normal lead styphnate or the like for first explosive material 105, 44 mg. lead azide or the like for second explosive material 106, 40 mg. PETN for explosive material 108 and 146-350 mg. RDX for explosive material 110. The material selected for the stud body must not be so brittle that the tensile shock wave itself, as it propagates through the material, or the explosive pressure, will cause the ultimate tensile stress of the material to be exceeded to produce premature and misplaced fracturing. In practice it has been found that steels of the type SAE 6150, SAE 1095, highly heat treated SAE 4130 or the like will badly fragment when employed in the instant invention. Nor can the material be so soft and ductile that the tensile shock wave is damped to a great extent upon reflection from the outer surface of the stud body and dissipate its energy by plastic flow deformation rather than separation. In this case, it has been found that soft ductile materials such as aluminum generally are unsatisfactory as stud body material for purposes of this invention, although aluminum alloys having mechanical prop-

erties approaching those of steel will produce satisfactory results.

Care must be taken in establishing the diameter of the hole into which the bolt stem fits. Since a free boundary, i.e., reflecting surface, is required on both sides of sharp edged corner 59, neither of these surfaces can be in intimate contact with the material of plates 19 or 20 which arrangement would tend to transmit the pressure pulse across the free boundary and reduce or eliminate the desired reflection from said surfaces. Therefore, very loose rather than tight or shrink-fit clearances must be used. In other words, there must not be an impedance match between the bolt material and the material in contact with the bolt surface in the area of the sharp edged corner. In cases where a loose fit is undesirable, for example, the diameter of the bolt above taper 13 can be reduced slightly to provide clearance between the bolt and the adjacent material. With such a construction, a resilient or plastic sleeve can be used about the bolt stem to achieve a tight fit yet provide a zone of dissimilar impedance, whereby effective reflection from the bolt surface is obtained.

The operation of the device of this invention can be seen through the sequence of events leading to the fracture of the stud body depicted in FIGURES 2, 3, 4, and 5. The length of the high explosive charge 15 has been purposely exaggerated to more clearly display the propagation of the shock waves.

Referring to FIGURE 2, a pressure shock wave 51 is generated upon detonation of explosive charge 15 beginning at point 50 and propagating outward at an angle α toward outer surface 57. Angle α is determined by vectorially adding the rate of propagation of the detonating wave along high explosive charge 15 to the rate of propagation of the shock wave through the stud body material in accordance with the equation:

$$\sin \alpha = \frac{C}{D}$$

where:

C=pressure pulse velocity in bolt material, and
D=detonation velocity of the explosive material.

For example, in the case using RDX, the detonation velocity is about 7.8 mm./microsec. and for steel, the shock wave velocity is about 5.9 mm./microsec. The resulting angle is about 40 degrees. The highest stresses in this case were achieved when $\theta=120^\circ$.

Referring to FIGURE 3 pressure shock wave 51 has reached outer surface 57. There results upon reflection of pressure shock wave 51 an inward propagating tensile (dilatational or rarefaction) shock wave front 52 due to the elastic nature of the stud material. As in the case of a mirror, the angle of reflection is equal to the angle of incidence of the wave front so that wave front 52 makes an angle α with outer surface 57.

Referring to FIGURE 4 pressure shock wave 51 is now closing in on corner 59. A second inward propagating tensile (dilatational or rarefaction) shock wave 53 is therewith reflected from tapered section 13. It has been found that best results are achieved when the angle θ at corner 59 is in the range of 90-140°. It can be seen that angle θ will determine the angle of collision of the two reflected tensile shock waves, which in turn, by vectorial addition, determines the tensile stresses to be found at the point of collision.

Referring to FIGURE 5, tensile shock waves 52 and 53 are in collision along line 54. Where the tensile stresses in one shock wave alone will be insufficient to exceed the ultimate strength of the stud material, the vectorial sum of the tensile forces upon collision is made to exceed said ultimate strength thus rending apart the stud body from corner 57 along a surface or plane defined by the rotation of line 54 about the longitudinal axis of stud body 10.

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Although the foregoing embodiment has been described in detail, there are obviously many other embodiments and variations in configuration which can be made by a person skilled in the art without departing from the spirit, scope or principle of this invention. Therefore, this invention is not to be limited except in accordance with scope of the appended claims.

What is claimed is:

1. A device for fastening components in contiguous relation and releasable upon detonation of a high explosive comprising in combination an elongated rod body having first and second ends adapted to receive means for securing said components in loose fitting relation along a central body area between said ends, said body area including a first generally cylindrical shock wave reflecting surface longitudinally inwards of said first body end, a second shock wave reflecting surface defining a substantially frusto-conical surface converging radially inwardly from said cylindrical surface toward said second body end with the junction of said first and second reflecting surfaces forming an interior angle therebetween of substantially 120° to define a sharp-edged peripheral corner, said second reflecting surface joining said first reflecting surface and a second generally cylindrical portion of reduced diameter, and said body defining a generally axial cavity extending from an opening at the first end of said body and extending in generally concentric symmetrical relation to said central body portion to terminate slightly beyond the second end terminus of said second converging reflecting surface, high explosive means disposed in said central cavity comprising a detonation initiating means, a planar detonation wave generating means and a symmetrical shock wave generating means including a high explosive coupled for ignition by said planar detonation wave generating means, said high

explosive means adapted upon initiation to provide a transverse detonation wave front which progresses longitudinally therealong to generate a symmetrical compressive shock wave propagating and diverging outwardly from the surface defining said cavity in said body, to be reflected inwardly by said first and second surface areas of said body as tensional shock waves colliding along a surface converging inwardly toward said first body end from said corner, whereat said body is fractured to release said fastening device.

2. In a mechanical fastening device releasable upon detonation of a high explosive material, the combination in accordance with claim 1 wherein said detonation initiating means comprises lead styphnate and lead azide, said planar detonation wave generating means comprises a narrow confined column of RDX and said shock wave generating means comprises PETN with said PETN disposed adjacent the closed inner end of said axial cavity.

3. In a mechanical fastening device releasable upon detonation of a high explosive material, the combination in accordance with claim 1 wherein said high explosive charge has a minimum detonation velocity of 5 mm./microsec.

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